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Efficacy of Flocculating and Other Emergency Water Purification Tablets

By

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October 1989 - September 1991

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13. ABSTRACT (*Maximum 200 words*) Chlor-Floc (CF) emergency water purification tablets were tested for bactericidal, viricidal and cysticical efficacy; removal of turbidity and chemical agents in water at temperatures ranging from 5°C to 25°C; and storage stability at 5, 25 and 40°C. The minimal required reduction was achieved for bacteria, Rotavirus, and Giardia, but CF did not achieve the required reduction of Poliovirus at any of the temperatures or time periods investigated. Clarification of water was effective in turbid waters, but filtration through a cloth is necessary to prevent flocculated sediment from entering the canteen. Removal of chemial agents from water was a function of the solubility of the chemical agent, the rate of hydrolysis and the composition of the water. The free residual chlorine in CF tablets remained stable at 5°C and 25°C for 27 months, but declined rapidly after three months at 40°C and three days at 60°C. To be acceptable to the Military, the tablets must be approved and registered by the EPA and must be stable during normal storage for three years. Commercial Item Descriptions have been written for CF tablets and for a kit containing tablets, filters, and a water treatment bag. Both may be procured through the Defense General Supply Center, Richmond, VA.

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

PREFACE

The purpose of this investigation was to evaluate new water purification compounds in order to provide an alternative to the Globaline™ iodine tablet presently used by soldiers to purify canteen water. The project was initiated at the U.S. Army Natick RD&E Center in response to the Water Resources Management Action Group (WRMAG) meeting number 11, tasking 42 (1). A revised letter requirement for an individual chemical purifier as well as a mechanical water purifier was drafted 10 January, 1990 (2). The search resulted in the selection of commercially available Chlor-Floc (CF) Emergency Drinking Water Tablets (3).

The CF tablet has been assigned National Stock Number (NSN) 6850-01-352-6129 and is a Common Table of Allowance 8-100 medical expendable item (4). It is managed by and can be ordered from the Defense General Supply Center, Richmond, VA. The tablets will be a component of a kit issued to soldiers containing 36 chlorine flocculating tablets, 3 cloth filter pouches and one plastic water treatment bag, sufficient for a three day mission (5). The kit must conform to Commercial Item Description A-A-52122, 1993, entitled Kit, Water Purification, Emergency. A NSN will be assigned to the Kit and to each component of the Kit. This will permit one to order each item separately if desired.

The Department of the Army, Office of The Surgeon General, has approved the use of Chlor-FLoc tablets and all components of the water purification kit (6,7). Responsibility for preparation of doctrine for its use was assigned to the U. S. Army Medical Department Center and School, Fort Sam Houston, Texas (7,8).

The viricidal efficacy of CF tablets was determined by Dr. Bruce Harper, Project Leader, Dugway Proving Ground, UT (9); the cysticidal efficacy by Dr. Susan Boutros, Project Leader, Environmental Associates, Bradford, PA (10,11,12); the chemical removal by investigators at Geomet Technologies, Inc, Gaithersburg, MD, Frank Kelly, Director (13). The bactericidal efficacy, clarification and storage stability was determined by Edmund M. Powers, Project Officer, the U.S. Army Natick RD&E Center, Natick, MA. The initiation of contracts and/or transfer of funds and their management was accomplished by Natick.

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We thank Sergeant Carlos Hernandez, Robert Stote and summer student Carol Chrestensen for their technical assistance, the Subsistence Protection Branch, Food Technology Division, Food Engineering Directorate, for evaluating and recommending the packaging material for the tablets, and Samuel Cohen of the Soldier Science Directorate for producing the electron micrographs.

EFFICACY OF FLOCCULATING AND OTHER EMERGENCY WATER PURIFICATION TABLETS

INTRODUCTION

The American soldier has been using iodine tablets (14) to purify canteen water under emergency conditions in the field since 1952 (15). This Center was tasked by the Water Resources Management Action Group at its 11th meeting in 1987 to provide a water purification tablet which will eliminate the deficiencies experienced with the standard iodine tablet (1). The deficiencies identified with iodine tablets included slow kill of Giardia cysts at low temperatures, medicinal taste and odor, and the fact that undissolved solids, color and odor in field water are not removed.

A market search for a new emergency water purification tablet, or compound, was undertaken. The tablet had to be commercially available, nondevelopmental and satisfy the new military requirements. The search resulted in the selection of a tablet called Chlor-Floc™ (3). The Chlor-Floc (CF) tablets combine sodium dichloro-isocyanurate, the active ingredient, with proprietary flocculating agents that clarify the treated water by coagulating particles in the water as the water is being disinfected. The heavy coagulated particles settle out, leaving the water above the sediment clear. When dissolved in water, the active ingredient dissociates to hypochlorous acid and chloride ions depending on the final pH of the water. The tablet also contains a buffering system which buffers the treated waters to a pH that is most optimal to achieve disinfection of the water. Later, another new tablet became available called Aquapure™ (16). The Aquapure (AP) tablet was very similar to the CF tablet and contained the same active ingredient, so it was also evaluated and compared to CF.

The objectives of the testing were to validate and verify the effectiveness of CF tablets for: (a), the destruction/removal of microorganisms, selected chemicals, and metals from water; (b), the clarification of water; and (c), the stability of CF tablets during storage at different temperatures.

MATERIALS AND METHODS

General Procedures

The procedures and standards used were in accordance with U.S. Environmental Protection Agency's (EPA) "Guide Standard and Protocol for Testing Microbiological Water Purifiers"(17), unless indicated otherwise. Standard microbiological analytical procedures were used (18,19,20). Testing at each condition was repeated a minimum of three times. Results presented in this report are the averages of at least three trials.

Tablets

Chlor-Floc tablets (lot# Z/1, Expires June 92) were manufactured by the Control Chemical Company in South Africa. Their agent in the United States is Deatrick and Associates Inc, Alexandria, VA 22302. The tablets are registered by the United States Environmental Protection Agency (EPA) under EPA No. 57425-SA-001. The active ingredient is 2.5% sodium dichloro-isocyanurate (sodium dichloro-s-triazinetrione). One 600 mg tablet provides 1.4% available chlorine (8 ppm free residual chlorine) and enough flocculating agent for the clarification and disinfection of one liter of water at 10 °C to 25 °C. Flocculating agents are proprietary. Total contact time specified is 20 minutes except at 25 °C where it is only 12 minutes. At 5 °C, two tablets and a contact time of 20 minutes are required per liter of water. Tablets were used as instructed by the manufacturer at 5 °C, 25 °C and 40 °C for several time periods ranging from 5 minutes to 120 minutes (9,10,11,12).

Aquapure (AP) tablets (lot #C3002, purchased March 29, 1990) were manufactured by the World Resources Company, McLean, VA and were used as instructed. The U.S. EPA is being petitioned by the Company to grant the registration of AP tablets which contain the same active ingredient as CF tablets. One tablet per liter of water was used at 10 °C and above and two tablets per liter of water at 5 °C (9,11,16). The AP tablets also contain proprietary flocculating agents and perform in the same manner as CF. They were also tested in the same manner as CF.

Iodine (Globaline™) tablets (14) used in these studies were manufactured by Van Ben Industries, Long Island, NY. They are also manufactured by the Wisconsin Pharmacal Company, Jackson, WI 53151, for the Army and under the label Potable Aqua™ for civilian use. They were used as per instructions and were compared with CF in parallel studies.

Tablet Package

Testing of packaging material was performed in accordance with procedures of the American Society for Testing Materials (ASTM). The commercially packaged CF tablets were subjected to vibration testing (ASTM D999), drop testing (ASTM D775), compression testing (ASTM D642) and storage at 38 °C/95% relative humidity. Tablets were withdrawn from storage every two weeks and tested for free residual chlorine. Materials commonly used for military packaging were tested concurrently. Each tablet was in a heat sealed trilaminated pouch.

Test Waters

Biocidal efficacy tests (9,10,12) were conducted in EPA #2 test water (17) and several natural waters from rivers and lakes. Chemical removal tests were conducted in EPA #2 test water and in distilled water (13).

Bacterial Challenge

Bacteria. The bacterial agents were *Klebsiella terrigena* [ATCC 33257, (18)], *Escherichia coli* (ATCC 15597), and *Pseudomonas aeruginosa* (QM-B-1517). Cultures were grown on Plate Count Agar (PCA, Difco, Detroit, MI) at 35 °C for 4 hours.

Inoculum. Cells were washed off PCA, suspended and diluted in 0.0145 M-Saline (21). The inoculum was adjusted turbidimetrically in a Ratio/XR turbidimeter (Hach Company, Box 389, Loveland, CO).

Challenge. One liter of test water was inoculated to achieve 1 to 10 million cells per mL (1 to 10 billion per liter) before addition of water purification tablets (17). Temperature of the water was equilibrated at 5 °C, 25 °C, and 40 °C.

Total aerobic counts. Trypticase Soy Agar (TSA, Difco) or PCA were used for total recovery of microorganisms from water.

Coliform Counts. Selective recovery of injured and uninjured coliforms (Klebsiella and Escherichia) after treatment, whether inoculated into test waters or naturally present in water, was accomplished on an injury repair medium consisting of TSA overlaid with Violet Red Bile Agar (VRBA, Difco) after incubation of TSA at 35 °C for two hours (20,22,23).

Plate Counts of Flocculated Sediment in Water Treated With Chlor-Floc Tablets

To determine the survival of bacteria in the flocculated sediment (floc) of water treated with CF tablets, one liter of river water in triplicate flasks was inoculated with 3 to 10 x 10^6 E. coli per mL at 25 °C. The water was treated with one CF tablet as per manufacturer's instructions (3) for a total time of 20 minutes. Plate counts of the clarified water were performed on an injury repair medium consisting of TSA overlaid with VRBA after two hours at 35 °C to recover injured as well as uninjured cells (20,22,23). The floc was then resuspended and harvested by filtration through 0.4 um filters (Millipore, Bedford, MA). Two grams of the recovered floc were resuspended in 18 mL of 0.0145 M saline (21) and plate counts were performed on the same repair medium.

Virus Challenge

The challenge viruses were Poliovirus type 1 and simian Rotavirus (9,17). Water temperatures were 5 °C, 15 °C and 25 °C .

Cyst Challenge

The challenge agent was Giardia muris cysts (10,11,12). Water temperatures were 5 °C, 15 °C and 25 °C.

Chemical Agent Challenge

The challenging chemical agents were arsenic (As), hydrogen cyanide (HCN), Lewisite (L) and mustard (HD). Challenge levels were 2.5 times maximum acceptable levels (MAL) specified for drinking water (24). Water temperatures were 5 °C and 10 °C. Two tablets per liter of water were used at 5 °C and one tablet at 10 °C. Total contact time was 21 minutes. Standard analytical and monitoring methods were used (18,19) as well as those developed by the U.S. Army (see reference 13).

Measurement of Free Residual Chlorine

Free residual chlorine produced by CF tablets dissolved in water was determined by amperometric titration (Wallace and Tiernan Titrator, series A-790, Belleville, NJ). Accuracy of the amperometer was checked with a standard chlorine solution. The standard was prepared by adding 1 mL of Clorox™ to 1 liter of deionized water to provide a 50 ppm stock chlorine solution.

Turbidity Measurements

Turbidity and clarification of test waters were determined with a Ratio/XR turbidimeter (Hach Company, Box 389, Loveland, CO) and were expressed as nephelometer turbidity units (NTU).

Total Dissolved Solids

Total dissolved solids (TDS) were measured with a Myron L DS meter, model 532 T1 and T2. Standard solutions of known conductivity were purchased from Myron L Company, Carlsbad, CA 92009-1598.

Cloth Filter Pouch

The cloth material selected for filtering water after treatment with Chlor-Floc is 100% cotton, bleached, Oxford product # 202307. It weighs 7 ounces per yard and has an air permeability of 56 to 64 ft^3 min/ft^2. It is available from Holliston Co., P.O. Box 478, Kingsport, TN, 37662. The filter pouch is fabricated with a double layer of the cloth with a double stitched sideseam. It is 6 inches long and 2 inches in diameter (5).

Testing For Halogenated Organic By-products in Chlor-Floc Treated Water

Test waters were prepared with deionized water containing 100 ppm humic acid salt (Aldrich Chemical Company, Milwaukee, WI) and adjusted to pH 9.0 with 1 N-NaOH. Two CF tablets were added to one liter of the humic acid water at 25 °C. The water was mixed continuously on a magnetic stirrer in the dark for 72 hours. Samples were withdrawn after 12 minutes, 2 hours and 72 hours. Chlorine residuals were quenched with 0.072N sodium thiosulfate (25) to stop the reaction between chlorine and the humic acid. Duplicate samples were analyzed for volatile organohalides by methods based on EPA method 524.2, purge and trap gas chromatography/mass spectroscopy using a capillary column (26). Quantitation was accomplished by inclusion of 100 nanograms of N-Nonane, injected directly onto the trap. Ten mL samples were used in each run. The same procedure was used for water containing two iodine tablets.

User Field Test

Twenty-three soldiers participated in a field test of CF and iodine water purification tablets at Lake Cochituate, Natick MA (Appendix A). The lake water picked up at the shoreline was green with algae growth and contained leaves, stems and sand. Because of the heavy algae bloom two

tablets per liter were used. The purpose of this test was to determine the "ease of use" of the CF tablet in the field. The water was not consumed following treatment. Volunteers were given a questionnaire and participated in focus group discussions of the CF and iodine water purification systems.

Taste Test

Consumer taste panels of forty members selected at random from Natick personnel compared tap water treated with CF and iodine tablets and equilibrated to 5 °C, 25 °C and 35 °C (Appendix B). Five quarts of tap water at each temperature were treated with the equivalent of one CF tablet per quart of water as per manufacturer's instructions. The water was filtered through cloth following treatment and maintained at the proper temperature by means of a water bath. Tap water treated with iodine tablets (Globaline) was prepared in the same manner (but was not filtered) by dissolving the equivalent of two tablets per quart of water. Because there was no demand at 5 °C and 25 °C the residual chlorine and iodine levels were adjusted to 4 ppm prior to testing. At 35 °C, residuals were reduced to 4 ppm without adjustment. The standard 9-point hedonic scale was used for acceptance ratings.

RESULTS

Bactericidal Efficacy

Tables 1 to 3 show that CF tablets effectively reduced or destroyed bacteria in both test water and a variety of natural waters. Table 1 shows that a six log reduction of E. coli, K. terrigena and P. aeruginosa was achieved in test water as required (17). Although the treatment times were 20 minutes or more, all three bacteria were killed and/or removed within 5 minutes. The same results were obtained with the Army's Globaline iodine tablets, tested in parallel with CF tablets. Triplicate trials were conducted.

Indigenous bacteria, including coliforms, in several natural waters were reduced to zero with the exception of harmless sporeforming bacteria found in water as shown in Table 2. Free residual chlorine (FRC) levels depended on the chlorine demand of the water treated and the number of tablets used. When two tablets were used in water below 10 °C, FRC ranged from 4.1 ppm in the Concord River, MA to 14.6 ppm in Cochituate Lake, MA. In Lake Cochituate water at 9 °C one tablet was inadvertently added instead of two tablets. Consequently, the residual chlorine was only 1.8 ppm, which still gave 100% kill. When one tablet was used at 10 °C or higher, FRC ranged from 4 ppm in the Charles River, MA to 7.1 ppm in Walden pond, MA. Although the waters varied in pH, the tablets consistently buffered the different waters to pH 4.1 to 4.3. Aquapure tablets tested in the same waters produced approximately the same bacterial kill but buffered the water from pH 6.2 to 6.4 and had lower FRC levels (16).

Table 1. Recovery of bacteria in challenging test water[a] before and after treatment with Chlor-Floc tablets

	Mean[b] Bacteria per mL	
Bacteria	Before treatment	After treatment[c]
E. coli	10,000,000	0
K. terrigena	10,000,000	0
P. aeruginosa	10,000,000	0

[a]EPA #2 test water, pH 9 (17). Final average pH was 4.4.
[b]Average of three trials
[c]Treatment was with one tablet at 5 °C, 25 °C and 40 °C.

Table 2. Bactericidal efficacy of Chlor-Floc water purification tablets in natural waters of Massachusetts

			Indigenous bacteria per mL						
			Before treatment			After treatment			
Water source	Water temp. (°C)	TDS[a] (ppm)	APC[b]	Coliforms	pH	APC	Coliforms	pH	FRC[c]
Walden pond	5	150	300	137	5.5	0	0	4.2	-
Walden pond	10	60	1190	88	5.9	0	0	4.1	7.1
Charles river	11	170	3800	330	5.8	82[d]	0	4.2	4.0
Concord river	9	150	71	49	5.5	0	0	4.1	4.2
Sudbury river	5	130	39	0	5.6	0	0	4.2	-
Lincoln creek	9	40	4200	271	5.9	15[d]	0	4.1	12.1
Dudley pond	11	160	101	72	6.4	0	0	4.3	6.8
L. Cochituate	4	200	84	46	6.2	18[d]	0	4.1	14.6
L. Cochituate	9	175	93	11	5.2	0	0	4.1	1.8
Sherman bridge, Sudbury river	5	160	250	28	6.0	13[d]	0	4.1	14.0

[a]Total dissolved solids
[b]Aerobic plate count
[c] Free residual chlorine in ppm.
[d]Spore forming bacteria

Table 3 shows the destruction and removal of indigenous microflora as well as E. coli inoculated at more than a million/mL into five natural waters from different parts of the world, at 5 °C and 25 °C. No bacteria were recovered after treatment of one liter of the water with two tablets for 20 minutes at 5 °C, or with one tablet per liter after 12 minutes at 25 °C. The pH varied from 5.8 to 7.5 and total dissolved solids (TDS) ranged from 70 to 210 ppm.

Table 3. Removal of Escherichia coli and indigenous bacteria in natural waters at 5 and 25 °C before and after treatment[b] with Chlor-Floc tablets

			Mean[a] bacterial count per mL		
Water	TDS (ppm)	pH	Bacteria	Before treatment	After treatment[b]
Cochituate Lake (MA)	210	5.8	E. coli	$3\text{-}5 \times 10^6$	0
			Indigenous	30 to 5×10^6	0
Delta River (Alaska)	120	7.5	E. coli	$5\text{-}10 \times 10^6$	0
			Indigenous	47 - 130	0
Java Creek (Alaska)	105	7.2	E. coli	$2\text{-}10 \times 10^6$	0
			Indigenous	21 - 80	0
Panama River (Panama)	70	7.3	E. coli	$1\text{-}10 \times 10^6$	0
			Indigenous	$1\text{-}9 \times 10^4$	0
Sudbury River (MA)	130	6.4	E. coli	$5\text{-}6 \times 10^6$	0
			Indigenous	690 - 1400	0

[a] Three or more trials
[b] Treatment at 5 °C was two tablets for 20 minutes
Treatment at 25 °C was one tablet for 12 minutes

Bactericidal, Cysticidal and Viricidal Efficacy of Water Purification Tablets

The bactericidal, cysticidal and viricidal efficacy of CF tablets were compared to Aquapure and Globaline iodine tablets and summarized in Table 4. Bactericidal data are from Table 1. Cysticidal and viricidal data and additional time periods were presented in the contract reports (9,10,11). The minimum required log reduction (MRLR) was achieved for bacteria and Rotavirus (9) by all three tablets after only five minutes contact time at 5 °C, 15 °C and 25 °C. The reductions were actually 100% for both organisms. The viricidal efficacy of all three tablets for Poliovirus was still less than a four log (99.99%) reduction even after increasing the contact time of CF and AP to 40 minutes at all three temperatures and iodine to 60 minutes at 5 °C (9). Only CF reduced Giardia in excystation studies (10) by the required three logs (actual reduction was 100%) at all three temperatures after the prescribed 20 minute contact time. The results of mouse infectivity assays in a follow up study with Giardia muris were comparable to the excystation assays (12). The AP tablets (11) reduced Giardia cysts by only an average of 1.5 logs at the prescribed dosage and 20 minute time period and achieved the MRLR (actual reduction was 100%)

only by extending the contact time to 120 minutes at 25 °C (one tablet). By comparison, iodine tablets at 5 °C only achieved the MRLR (actual reduction was 100%) of Giardia by extending the contact time to two hours with two tablets and to three hours with one tablet (10). The cysticidal efficacy of iodine was tested only at 5 °C. The poor efficacy achieved by AP for Giardia and Poliovirus may have been due to a combination of low residual chlorine concentrations, storage instability (16), and higher pH than was achieved with CF (9,10). Several investigators have reported increased cysticidal efficacy at low pH (< 6) rather than at high pH because at low pH, hypochlorous acid, an effective cysticide, predominates (27,28). The stability of the active ingredient in AP tablets must be improved in order to maintain optimum and high chlorine residuals for at least three years as required by the Military (16). Incorporation of a more acidic buffer to produce lower pH values in treated water may also be required.

The required total treatment (contact) times are 35 minutes regardless of water temperature for iodine tablets; 12 minutes at 25 °C, and 20 minutes at 5 °C to 15 °C for CF and AP tablets. However, for the sake of simplicity and to insure microbiological destruction and removal, soldiers will be instructed to treat all waters with one CF for 20 minutes. Although only prescribed dosages are presented in Table 4, one tablet at 5 °C effectively reduced bacteria, Giardia and Rotavirus in less than 20 minutes (9,10). The recommended dosage for iodine is two tablets per liter of water, whereas the dosage recommended by the manufacturer for CF and AP is two tablets only at 5 °C and one tablet at 10 °C and higher. Sufficient chlorine residuals for CF and iodine residuals for Globaline iodine tablets were achieved, to be microbicidal at all temperatures (9,10).

Table 4. Bactericidal, viricidal and cysticidal efficacy of Chlor-Floc, Aquapure and Globaline iodine tablets at 5, 15 and 25 °C at prescribed dosage.

			Average log reduction		
Agent	MRLR[a]	Minutes	Chlor-Floc	Aquapure	Iodine
Bacteria	6	5	>6	>6	>6
Rotavirus[b,c]	4	5	>4	>4	>4
Poliovirus[b,c]	4	20	2.4-2.5	1.3-1.7	1.4
		40	2.6-2.7	1.9-2.3	2.2
		60	-	-	3
Giardia[c,d]	3	20	>3	1.5	1.9
		30	>3	2.4	2.3
		40	>3	1.9-2.8	-
		45	-	-	2.98
		60	-	-	2.99
		120	-	>3	>3

[a] Minimum required log reduction (17). ">" symbol indicates 100% actual reduction.
[b] Reference 9
[c] Iodine was tested against enteroviruses and *Giardia* only at 5 °C.
[d] Reference 10

Influence of pH on the Bactericidal Efficacy of Chlor-Floc and Iodine (Globaline) Tablets

Table 5 shows the bactericidal efficacy of CF at 25 °C in deionized water buffered between pH 4 and pH 10, compared to iodine tablets. Although the water was highly buffered the tablets reduced the pH slightly. One CF tablet per liter completely killed two to eight million *E. coli*/mL at a final pH ranging from 3.8 to 7.0 at which there were no survivors. At pH 8.3, CF was slightly less effective, allowing 6.0% of the cells to survive. Chlor-Floc was not bactericidal at all at a final pH of 9.3. Iodine was bactericidal at pH 3.8 through pH 9.0.

Table 5. Bactericidal efficacy of Chlor-Floc and Globaline iodine tablets after treatment of water buffered at different pH values.

Initial Buffered pH[b]	Survival of *E. coli*[a]			
	Chlor-Floc		Iodine	
	pH	% Survival	pH	% Survival
4.0	3.8	0	3.8	0
6.0	5.0	0	5.6	0
8.0	7.0	0	7.2	0
9.0	8.3	6	–	–
10.0	9.3	100	9.0	0

[a] *E. coli* added to water ranged from 2×10^6/mL to 8×10^6/mL
[b] pH 4, 0.1 M Sodium acetate and acetic acid
pH 6-8, 0.1 M Phosphate buffer
pH 9-10, 0.1 M Glycine and sodium hydroxide

Bactericidal End Points of Free Residual Chlorine Issued from Chlor-Floc Tablets.

Table 6 shows the bactericidal endpoints of the FRC from CF tablets and the pH in a buffered water, Cochituate Lake water, and EPA #2 test water (17) inoculated with 2-4 million *K. terrigena* per mL. The objective was to determine the bactericidal endpoint of free residual chlorine (FRC) in canteen water following treatment of the water with a CF tablet. Chlor-Floc tablets were dissolved in each of the waters tested at 25 °C. The FRC concentrations were then adjusted by preparing dilutions with the same water and were verified by amperometric titration. In all three waters, 100% destruction of *K. terrigena* was achieved at 0.5 ppm FRC and higher. Below 0.5 ppm FRC the destruction was variable. Therefore, even in a worst case water such as EPA#2 test water, contaminating bacteria, represented by the test organism, that inadvertently enter the canteen water after treatment with CF tablets, will be killed within 30 minutes if the FRC is at least 0.5 ppm at 25 °C. In most waters treated with one CF tablet the FRC can be expected to be four to six times greater.

Table 6. Destruction of *K. terrigena* at various concentrations of free residual chlorine from Chlor-Floc tablets dissolved in three different waters.

Free Residual Chlorine (ppm)	Destruction of *K. terrigena*[a] after 30 Minutes					
	Buffered water[b]		Lake Water		EPA #2 Water	
	%Kill	pH	%Kill	pH	% Kill	pH
1.0	100	7.0	100	5.2	100	4.4
0.7	100	7.0	100	6.1	100	4.5
0.5	100	7.0	100	6.2	100	4.3
0.4	100	7.0	24	6.2	12	4.6
0.3	28	7.0	--	--	--	--
0.0	0	7.0	0	6.4	0	9.0

[a]Cell concentration was 2 to 4 x 10^6/mL
[b]1/15 M Phosphate Buffer

Survival of Microorganisms in Flocculated Sediment

Figure one indicates that viable *E. coli* may remain in the flocculated sediment (floc) after treatment of some waters with Chlor-Floc tablets. Although the bacteria were killed or removed from the clarified portion of the treated water after 20 minutes, they were still viable in the floc after more than 60 minutes. Surviving *E. coli* in the floc ranged from 10^4 to 10^7 per liter from an intial population of 10^{10} per liter. Similar results were also obtained with *Klebsiella terrigena* seen in Figure 2. a scanning electron micrograph of the floc harvested after 20 minutes of treatment. Arrows point to aggregated cells coated with the floc material. The flocculation process in turbid waters containing a high level of suspended matter, such as the five river waters shown, may protect bacteria by coating the cells so that chlorine can not reach them. Aggregation of cells by the flocculants and /or chlorine (29) contained in CF undoubtedly provides some protection against the disinfectant (30). Viable *Giardia* cysts could not be detected in the floc because the floc obstructed the standard microscopic observation of the cysts. However, it appeared that the flocculation process entrapped the cysts so that they were physically removed from the water (10). Enteroviruses were not recovered from the floc (9). It should be pointed out that the concentration of cells of all test microorganisms inoculated into the waters was much higher than would be expected in most waters encountered and may also play a part in the survival of microorganisms.

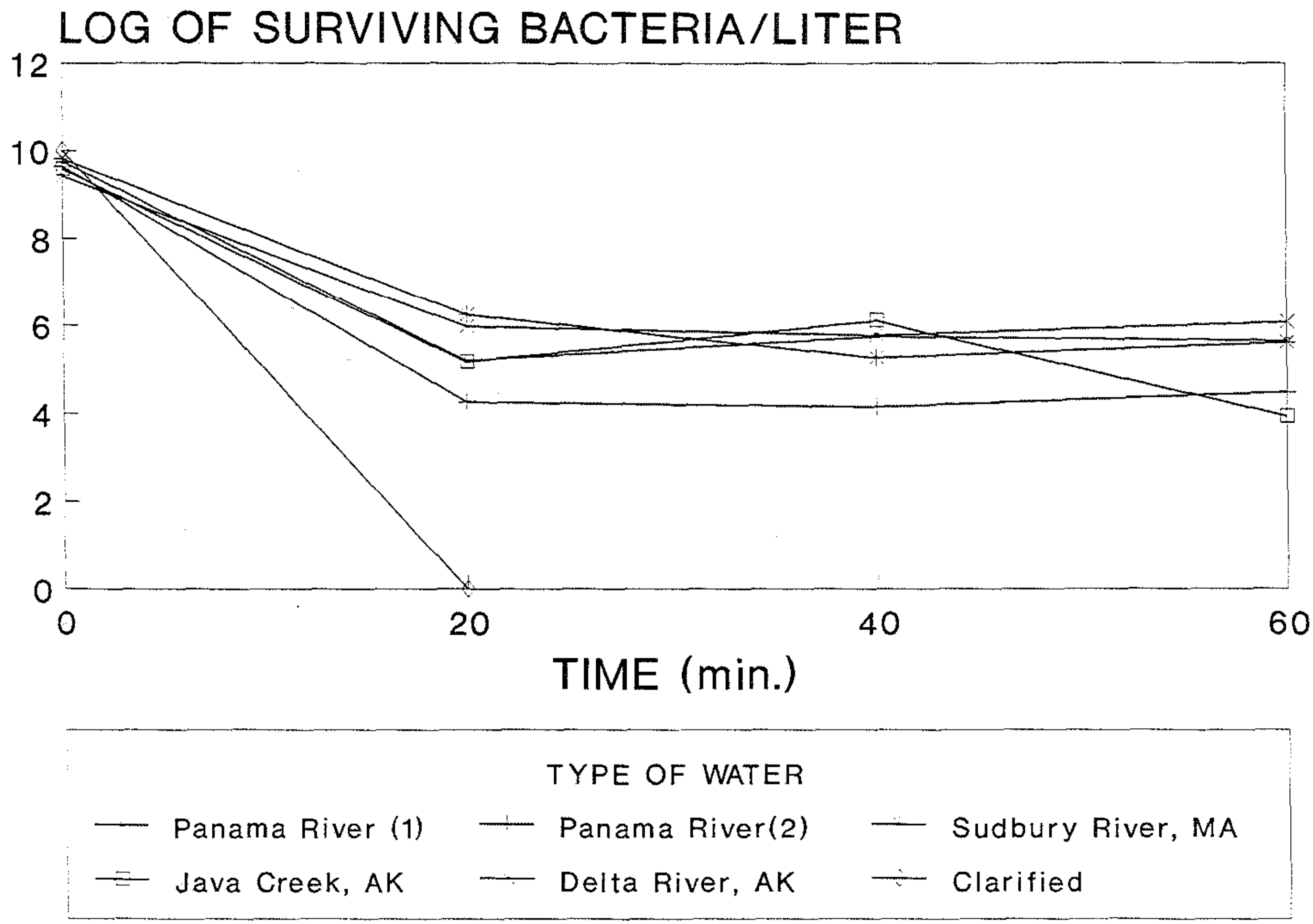


Figure 1. Bacterial survival in the flocculated sediment of Chlor-Floc-treated water.

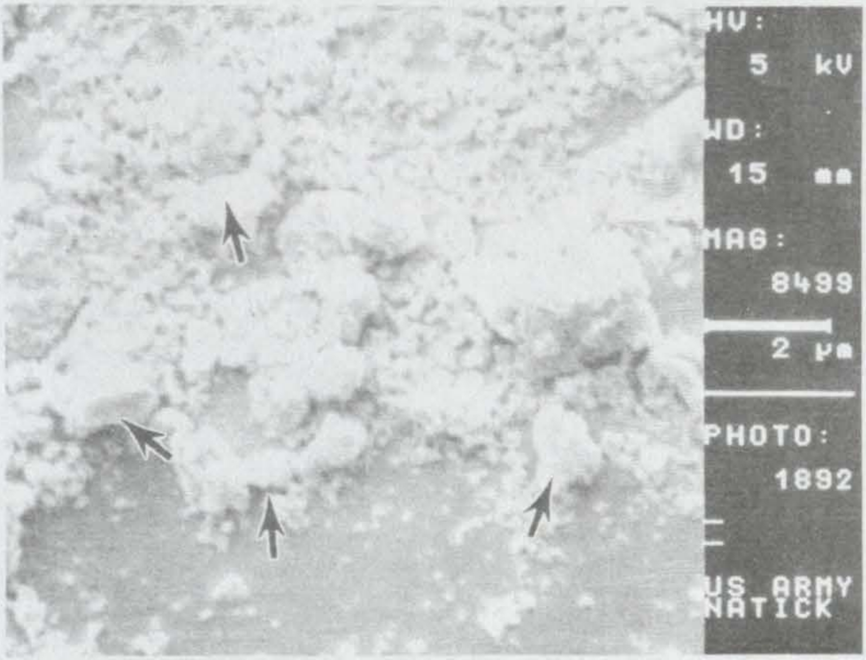
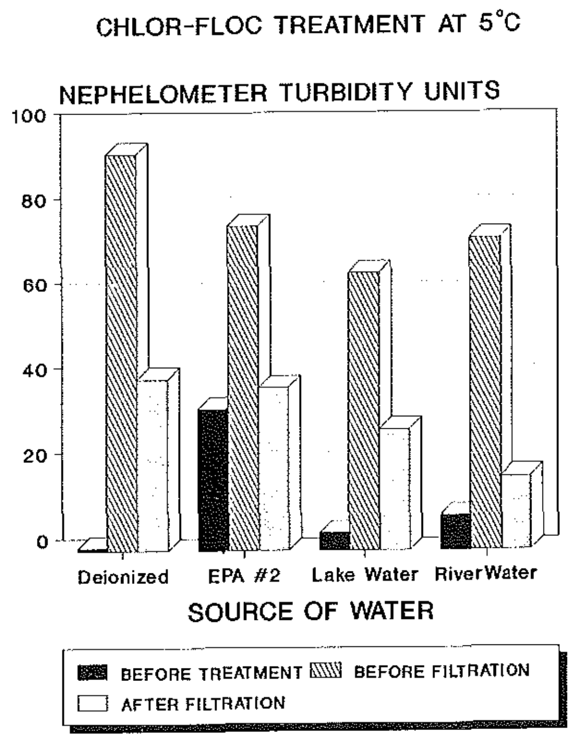


Figure 2. Electron micrograph showing cells of K. terrigena in the flocculated sediment produced in water treated with a Chlor-Floc tablet.



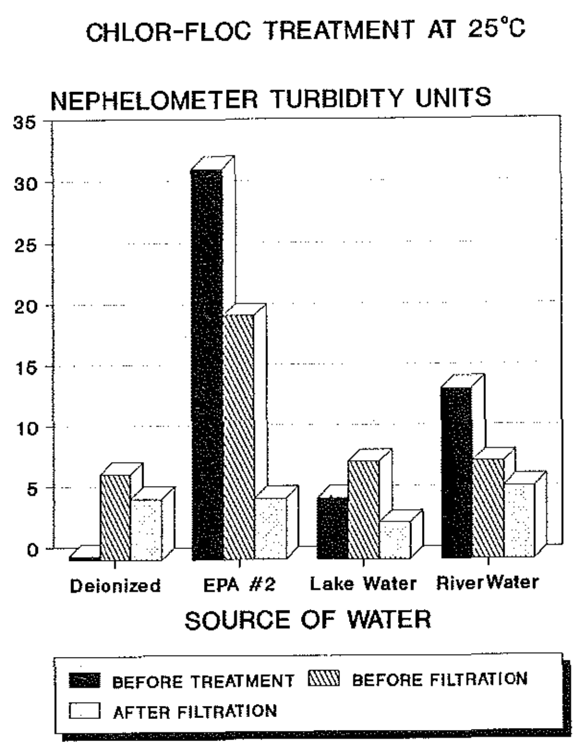


Figure 3. Clarification of four different waters at 5°C and 25°C by Chlor-Floc emergency water purification tablets.

Clarification of Water

In cold (5 °C) water and in clean water such as lake and deionized water at 25 °C, the turbidity (NTU) was increased by treatment with the CF tablets as shown in Figure 3. It is suspected that components of the tablet, which are insoluble in cold water and too small and light to settle out, are responsible for the increased turbidity. However, filtration of the treated water through a cloth filter sock provided by the Chlor-Floc distributor (Deatrick and Associates, Alexandria VA) reduced the turbidity considerably at 5 °C, so that it was drinkable, and to levels hovering around 5 NTU's at 25 °C. The maximum allowed turbidity in municipal-treated water is 5 NTU's (31,32). However, to the naked eye, water having a turbidity of 10 NTU's or less appears clear and suitable under emergency or field conditions. The effectiveness of the flocculating agents (proprietary) contained in CF tablets is demonstrated at 25 °C. At 25 °C, CF tablets reduced the turbidity of the EPA #2 test water and the river water, which were turbid or dirty to begin with, before filtration. Filtration of the treated water through a cloth reduced the turbidity even further to approximately five NTU's. The dirtier the water the more effective the flocculants become, because there are sufficient particles to coagulate and settle out. A more efficient cloth filter, cited on page four, was provided by a 100% cotton material, Oxford product #202307, Holliston Co., Kingsport, TN 37662 (5).

Evaluation of Four Cloth Filters for Clarification Efficiency

Test waters #1 and #2 were prepared by adding a measured amount of a dehydrated clay blend to one liter of deionized water. Test water #3 was prepared by dissolving a Chlor-Floc (CF) tablet in one liter of deionized water. Test water #4 was prepared by treating one liter of clay water with one CF tablet, as per manufacturer's instructions. All four filters were tested with the same water sample preparation by passing 100 mL through each filter. Except for sample #4, particles were kept in suspension by continuously stirring with a magnetic stirrer. In sample #4, the particles were allowed to settle out, by the action of the tablet, and only the clarified water was passed through each filter. Turbidity of the water samples was measured as NTU's at room temperature, before and after filtration, with a Hach Ratio/XR turbidimeter (Model #43900).

Table 7 shows that the coffee sock was not an effective filter and reduced the turbidity of test waters 1, 2 and 4 by only 17% to 22%. The other three filters gave comparable results, with the Natick 2307 filter giving a slightly lower turbidity in three out of four test waters and also a slightly lower overall average turbidity. However, the Milbank filter is considered to be too large (18"L x 7"W), cumbersome and heavy (80 g) for the individual soldier. In addition, water will not pass through the material unless it is completely soaked by squeezing water through the bag while underwater, as per instructions attached to the filter sock. Since soaking must of necessity be done with a contaminated water source (the only water available), both the exterior and the interior will be contaminated before the water is filtered. It may be for this reason that instructions attached to the filter direct one to treat

the water in the canteen after filtration through the Milbank filter. It is also very difficult to rinse out mud and other particulates from the filter for reuse. Obviously, CF tablets are not intended to be used with the Milbank filter. For these reasons the Milbank filter is unsuitable for the purpose of this investigation.

An additional consideration in the selection of filter material was the ability to remove cysts of Giardia. The DA filter was not effective for the removal of Giardia (personal communication, Dr. Steven Schaub, Fort Detrick, Frederick, MD). However, Natick contract studies (12) showed that the Natick 2307 filter removed 96% of the Giardia cysts remaining after treatment with CF.

Table 7. Filtration efficiency of four cloth filters.

		Average Turbidity (NTU)				
			After Filtration[a]			
Test Water[b]	Chlor-Floc Tablets/L	Before Filtration	2307	Coffee Sock	Milbank	DA
1. Clay	0	42	17	35	14	20
2. Clay	0	40	13	33	14	17
3. DIW+CF[c]	1	56	1	11	3	2
4. Clay + CF	1	9	1	7	2	1

[a]Filters:
2307 - Natick 202307, 100% cotton (5)
Coffee Sock - Coffee Sock Company, P. O. Box 10023, Eugene, OR 97440
Milbank - Catalog No. A. F. 0005, M & Co (N), Australia.
DA - Cotton flannelette sock provided by Deatrick and Associates, Alexandria, VA.
[b]Except for sample #4, particles were kept in suspension and filtered (see text.
[c]CF tablet dissolved and kept in suspension in deionized Water .

Stability

The stability of the active ingredient in CF tablets, sodium dichloroisocyanurate, was determined by amperometric titration of free residual chlorine (FRC) measured in parts per million (ppm) in chlorine-demand-free deionized water. Table 8 shows the FRC concentrations in CF tablets selected at random shortly after production and immediately upon receipt. The available chlorine level required in each tablet is 8 ± 1 ppm. Lot 92607 was defective due to a production problem and was returned to the manufacturer. The two subsequent lots received were acceptable. Only one tablet in lot Z/1 had a FRC level below 7.1 ppm, and in lot 922/1 only one tablet had a FRC level below 8.2 ppm. It is evident that the FRC level of each lot purchased must be checked and this is in fact required by the Military Specification and purchase documents.

Table 8. Free residual chlorine in Chlor-Floc tablets at receipt

Lot #	Range[a]	Mean	SD
92607	3.0–7.6	5.1	1.6
Z/1	6.5–9.2	8.5	0.74
922/1	7.0–8.4	8.2	0.46

[a] Range of 20 tablets selected at random

The stability of the FRC in CF tablets after storage in their original package at 5 °C, 25 °C and 40 °C for up to 27 months is shown in Table 9. Storage is continuing for 3 years. The average FRC concentration declined at 40 °C by 13% after 6 months and by 70% after 27 months, but remained relatively stable at 5 °C and 25 °C for 27 months.

Table 9. Stability of free residual chlorine in Chlor-Floc tablets stored in their original package at 5 °C, 25 °C and 40 °C.

Months stored	Average percent free residual chlorine[a] (ppm)[b]		
	5 °C	25 °C	40 °C
0	100	100	100
3	100	100	100
6	99	98	87
9	99	97	80
18	97	98	43
22	96	98	32
27	96	95	30

[a] Tablets were dissolved in deionized chlorine-demand-free water.
[b] Values are the average of two tablets in parts per million

The stability of CF tablets at elevated temperatures was determined at 60 °C. Table 10 shows that the FRC in tablets stored in their original package was reduced by 50% after 3 days, but stabilized at 35 to 36% from 7 to 101 days. Unpackaged tablets stored in plastic petri plates retained 100% of the FRC for 101 days. Therefore, tablets in sealed containers should not be stored at excessively high temperatures or in direct sunlight.

Although the commercial package for CF tablets was suitable for military use, the packaging material for such tablets must conform to the requirements of CID A-A-52122 (4).

Table 10. Stability of Chlor-Floc tablets at 60 °C.

	Average free residual chlorine per tablet	
	Packaged	Unpackaged[a]
Days	%	%
0	100	100
3	50	94
7	36	100
21	31	103
30	35	100
50	35	100
101	36	100

[a]Unpackaged tablets were stored in open plastic petri plates.

Stability of Chlorine From Chlor-Floc Dissolved in Water

To determine how long FRC would remain at bactericidal levels after CF was dissolved in water, experiments were conducted that would demonstrate its stability in water. Chlor-Floc tablets were added to five different test waters equilibrated and stored at 5 °C, 25 °C and 35 °C. Phosphate buffer (pH 7) was tested only at 25 °C. Two tablets were added at 5 °C and one tablet at 25 °C and 35 °C. Amperometric titrations of FRC were for conducted periodically for 72 hours.

Figure 4 shows that FRC was most stable in deionized water at all three temperatures and in pH 7 phosphate buffer at 25 °C. Bactericidal levels of FRC ($\geq$0.5ppm), as shown in Table 6 were maintained in all waters for 72 hours at 5 °C; for 48 hours at 25 °C; and for 24 hours at 35 °C. The implications for the soldier are that he or she can safely drink from the canteen for 72 hours if the water remains cold. However if it warms to 35 °C, the water should be consumed or discarded within 24 hours.

Chemical Agent Removal

Test waters at 5 °C and 10 °C were challenged with chemical agents at 2.5 times the maximum acceptable level (MAL) specified for short term (7 consecutive days) consumption of water (13,24). Removal of the chemical agents depended on temperature and composition of the water. Although CF did not remove all of the chemical agents from water, Table 11 shows that 50 % or more of all four agents were removed from distilled water and EPA test water #2 at 5 °C, with the exception of HCN. There was no removal of

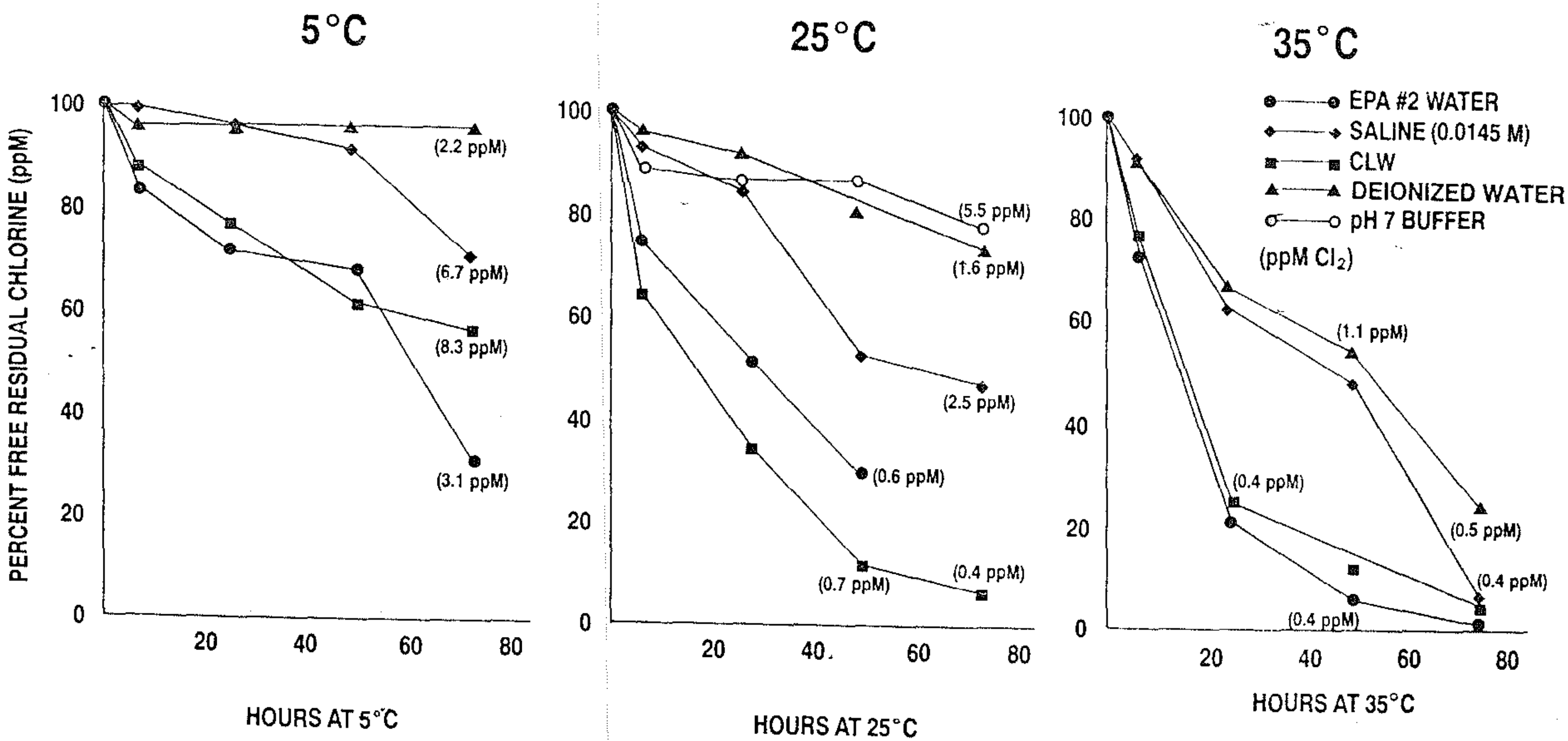


Figure 4. Stability of free residual chlorine in five different waters at 5°C, 25°C, and 35°C.

HCN in EPA #2 test water at 5 °C or at 10 °C. The percent removal of all chemical agents was greater at 5 °C than at 10 °C. Because mustard (HD) and lewisite (L) are insoluble and hydrolyze rapidly, they can not be detected directly in water. Analysis of L is based upon arsenic by-products which were detected. The hydrolysis products from HD may have been present in the water, but were not detected because the analytical test is specific for HD.

Table 11. Efficacy of Chlor-Floc in removing chemical agents from water.

		Percent removal			
		5 °C		10 °C	
Agent	MAL[b] (ppm)	DW[a]	EPA#2 Water	DW	EPA#2 Water
Arsenic (5 ppm)	2	62	76	46	56
HCN (50 ppm)	20	50	0	26	0
Lewisite (5 ppm)	2	58	54	38	54
Mustard (5 ppm)	2	>90	69	>90	60

[a]DW - distilled water.
[b]Maximum acceptable level (TB MED 577)

Trihalomethane

It has been reported that chlorination of water containing humic material produced trihalomethanes, notably chloroform, that are potentially carcinogenic (25,33,34). Trihalomethanes become more concentrated with increased pH, chlorine dosage, humic or fulvic acids and reaction time (35). However, Table 9 shows that even in pH 9.0 water containing as much as 100 ppm humic acid, harmful levels of trihalomethane by-products (chloroform) were not formed within 72 hours. The concentration of chloroform detected was at least 100 times less than the maximum concentration level permitted (35) 72 hours after adding two CF tablets per liter. The highest concentration of chloroform detected was 10 ppb after 2 hours which is 10 times less than the acceptable level. The levels of chloroform detected in water treated with iodine tablets were even lower.

Table 12. Trihalomethane formation in humic acid water treated with Chlor-Floc and Globaline water purification tablets.

Tablet	Tablets Per L	pH	Humic Acid ppm	Chloroform (ppb) 12 min	2 hours	72 hours	MCL[a]
Chlor-Floc	2	9	100	2 3	8 10	0.5 0.6	100
Iodine [b]	2	9	100	0.1 0.1	<0.02 0.02	0.04 0.02	100

[a]Maximum Contamination Level
[b]Globaline

User Field Demonstation

Results at Lake Cochituate, MA shown in Appendix A indicate that the overall use of the CF system (tablets, treatment bag and filter) by 23 soldiers as well as all other aspects of the system were rated slightly easy to moderately easy. Some difficulty, not related to the CF tablets, was encountered with the unique cone shaped plastic prototype water-treatment bag. The discharge tube at the bottom of the cone-shaped bag occasionally clogged due to stems and the heavy algae bloom. Use of this cone shaped bag was discontinued because it was considered to be impractical. The treatment bag finally recommended is shown in the diagram in Appendix C. The clearness and appearance of the CF treated water was rated significantly higher than the iodine system. No difficulty was encountered with the label instructions. The focus group discussions indicated that the soldiers preferred the CF system in the field because it provided them with "cleaner", "much more palatable" and less "murky" water than the iodine system. However, the questionnaire revealed that 74% of the soldiers would like to have the option of using either system in the field depending on the field conditions and time.

Taste Test

A consumer taste test (Appendix B) indicated that the overall acceptability of CF-treated tap water, while moderately disliked, was higher than iodine-treated water. The CF-treated water was rated significantly clearer, less medicinal tasting and had less aftertaste than iodine-treated water. Tap water was selected so volunteers could safely drink the water. However, the tap water had virtually no chlorine demand. Therefore, to avoid unusually excessive concentrations of chlorine, the free residual chlorine (FRC) levels were adjusted to 4 ppm to approximate the iodine concentrations. At 5 °C both the FRC and the iodine residual had to be diluted to 4 ppm in the respective waters. Water with lower FRC levels, as usually attained in most natural waters, undoubtedly would have been more acceptable. It was surprising that with the exception of untreated tap water the serving temperature had no effect on the acceptability or perceived intensities of the other attributes studied.

DISCUSSION

The biocidal efficacy, clarification and storage stability of Chlor-Floc tablets were verified and compared to iodine tablets. As a result of these studies CF tablets were endorsed by the U.S. Army Natick RD&E Center and were recommended as a suitable alternative to iodine tablets presently used by United State soldiers for emergency purification of field water. The product also received endorsement and medical clearance by the Office of The Surgeon General of the U.S. Army (OTSG) on July 22, 1992 (6) based on studies reported herein, as well as medically oriented studies of CF performed at Fort Detrick (36). Chlor-Floc was also endorsed by the Army Surgeon General of South Africa and has been in use by the South African Defense Forces for several years (37).

The CF tablets are commercially available. They received U.S. Environmental Protection Agency registration #57425-1 under the Federal Insecticide, Fungicide, and Rodenticide Act on February 16, 1989 (38). The CF tablets were accepted as a safe and effective disinfectant for recreational and emergency use in water at temperatures ranging from 5 °C to 25 °C . Acceptance was based on cysticidal data submitted by the manufacturer, which supported the effectiveness of CF as a water disinfectant against Giardia lamblia when tested in simulated turbid hard water at 5 °C to 25 °C (39). The cysticidal efficacy of CF was also supported by studies presented in this report (10,12).

Health hazard assessment of CF was conducted by the U.S. Army Environmental Hygiene Agency (6) for the Department of The Army, OTSG. No toxicity or other harmful effects was found associated with the proper use of CF, providing that label instructions are followed. Filtration of the treated water to remove the flocculated sediment and to prevent it from entering the canteen is essential. As reported herein, viable microorganisms were found in the sediment of some test waters, which may pose a potential source of infection. However, these waters were inoculated with millions of bacteria per mL. Survival in the floc may not be a problem in natural waters which usually would have much lower microbial flora. While CF tablets will remove some chemicals from water, they should not be depended upon for this purpose. Chlor-Floc tablets do not produce potentially harmful levels of halogenated organic compounds in water (Table 12).

There was no established guidance for determining challenge levels in water for chemicals, so the challenge levels selected were arbitrarily set at 2.5 times the MAL specified for short term (7 consecutive days) consumption of water (24). These levels may have been much higher than one would realistically find in natural waters. It is possible that lower challenge levels would be reduced to acceptable levels. The differences noted between the two test waters indicate that the type and composition of the water will have an influence on the removal of chemicals by CF tablets. Solubility of the chemical agents and the rate of hydrolysis will also have an effect on their detection. Lewisite can be detected only indirectly in water because it dissociates to arsenic compounds. Mustard (HD) may not be detected in the water because it hydrolyses very rapidly in water. The test used, which is specific for HD, does not detect hydrolytic products that may be present in the water (13). Nickel and copper ions were effectively removed from water (data not shown).

The failure to achieve the required log reduction of Poliovirus in this study (9) may be due to strain differences or experimental procedure and should be investigated further. The Fort Detrick Studies (36) confirmed that CF removed Poliovirus 1 at low temperatures even at high pH. Sensitivity of Poliovirus to chlorine has also been reported by other investigators (29,40,41) and the sensitivity of the closely related Rotavirus to chlorine was demonstated in this study by both CF and Aquapure tablets (9).

Aquapure Emergency Water Purification tablets (AP) displayed considerable promise in water purification, but were unstable during storage (16). However, AP tablets have been recently reformulated to improve the stability of the chlorine component (personal communication from World Resources, Inc.), which may improve its cysticidal and viricidal efficacy. This improvement should be verified by continuing these studies and initiating a new storage study with the reformulated AP tablets. An alternative procurement source is vital to military interests because it provides insurance against interruption or loss of supply.

Doctrine and training for use of CF by the soldier will be developed by the U.S. Army Medical Department Center and School, Fort Sam Houston, Texas in coordination with the Quartermaster Center and School, Fort Lee, VA (8). The U.S. Army Natick RD&E Center is assisting by providing technical data and expertise. Although the treatment of water with CF is not difficult, adequate training of each soldier is essential to obtain successful and consistent results.

To facilitate treatment of water in the field, the soldier will be provided with a kit (5), sufficient for a three day mission, that will contain tablets, cloth filters and a simple plastic water-treatment bag (see appendix C). MANPRINT-approved instructions will be embossed on the plastic bag. Water will be collected and treated in the plastic bag provided. Then the clarified water will be carefully decanted through the cloth filter pouch into the canteen. Treatment of water directly in the canteen is not recommended because of the potentially hazardous floc. Since studies presented in this report demonstrated that one CF tablet effectively reduced bacteria, Rotavirus and Giardia at 5 °C within 20 minutes (9,10,12), the soldier will be instructed to use one tablet per quart of water and treat the water for a total time period of 20 minutes regardless of water temperature. This will simplify the procedure considerably, although it is contrary to the manufacturer's instructions, because the soldier will not have to be concerned about selecting treatment time, temperature or differing number of tablets. Evaluation of the filter cloth demonstrated that it will clarify the water after treatment with CF even when the sediment is not allowed to settle. This is important for the soldier because, if necessary, the soldier can remain on the move after collecting the water and adding a tablet. Then any time after 20 minutes have elapsed the water can be filtered without waiting for the sediment to settle out. However, this process is not recommended for routine water purification because it will dirty the filter and may reduce its usefulness.

As a result of these efforts the soldier will be provided with an emergency water purification tablet (4) and kit (5) that can be used as an alternative to the iodine tablet when murky, turbid water encountered in the field needs to be clarified to make it drinkable (see appendix C). Clear, clean- appearing, odor-free water will encourage greater consumption, thus reducing casualties due to dehydration.

CONCLUSION

The Chlor-Floc Emergency Water Purification tablet was evaluated and was found to be a broader biocide than the Globaline iodine tablet under several potential use conditions. In addition, it effectively clarified turbid water. Endorsement of the tablet by the U. S. Army Surgeon General was received following a Health Hazard Assessment. As a result of these efforts, the soldier will be provided with an emergency water purification tablet and kit that can be used as an alternative to the iodine tablet when murky, turbid water encountered in the field needs to be clarified to make it drinkable.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-93/033 in the series of reports approved for publication.

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APPENDIX A

FIELD TEST OF CHLOR-FLOC AND IODINE EMERGENCY WATER PURIFICATION TABLETS

At LAKE COCHITUATE, NATICK, MASSACHUSETTES

AUGUST, 1992

APPENDIX A

Chlor-Floc Summary

Soldiers used two water purification systems to purify lake water; the Chlor-Floc system and the iodine tablets. Volunteers were given a questionnaire examining aspects of both systems. They also participated in focus groups in which they discussed their opinions of the Chlor-Floc and iodine water treatment systems.

Twenty-three soldiers from the Headquarters company at Natick RD&E Center participated in the test. The group consisted of 21 males and 2 females. The average age was 28 and mean time in the Army was 6 years. Only 9 soldiers reported they had used the iodine tablets before and none of them had ever used the Chlor-Floc or any other water purification system in the field.

The following table outlines the "ease of use" ratings obtained from questionnaire data on each system.

Table 1
Ease of Use Ratings
(N=23)

VERY DIFFICULT	MODERATELY DIFFICULT	SLIGHTLY DIFFICULT	NEUTRAL	SLIGHTLY EASY	MODERATELY EASY	VERY EASY
1	2	3	4	5	6	7

CHLOR-FLOC	$\bar{X}$
Overall ease of following the instructions	6.0
Ease of filling the bag with water	5.6
Overall ease of use	5.4
Ease of using the filter	5.2
Ease of transferring the water from the bag to the canteen	5.2
Ease of flushing out sediment at bottom of the bag	4.9

IODINE	$\bar{X}$
Overall ease of following the instructions	6.4
Overall ease of use	6.5

The iodine system ratings on ease of use were recorded in the "moderately easy" to "very easy" range. All Chlor-Floc aspects were rated between "slightly easy" and "moderately easy" except for "ease of flushing out sediment at bottom of the bag." This lower rating may be due to the large algae content in the water, which ultimately settled at the bottom of the bag. The most common problem with the Chlor-Floc system was when the straw-like extension at the bottom of the bag became clogged with debris. A paired _t_-test was performed on the mean ratings for overall ease of use. The iodine tablets were found to be significantly easier to use than the Chlor-Floc system ($t = -3.46$, df=22, $p < .01$).

All of the participants reported that they did not experience any difficulty following the instructions provided for each system. Instructions for both systems were rated "moderately easy" to "very easy" in Table 1.

The soldiers' satisfaction with the clearness of the treated water was also examined. The Chlor-Floc system received a significantly higher rating for clearness than the iodine system ($t = -5.48$, df=18, $p < .01$). No difference was found between the systems when comparing the ratings of satisfaction with the speed of treating the water. The mean satisfaction ratings for clearness and speed are presented in Table 2.

Table 2
Mean Satisfaction Ratings
(N=23)

VERY DISSATISFIED	MODERATELY DISSATISFIED	SOMEWHAT DISSATISFIED	NEITHER SATISFIED DISSATISFIED	SOMEWHAT SATISFIED	MODERATELY SATISFIED	VERY SATISFIED
1	2	3	4	5	6	7

CHARACTERISTICS	Chlor-floc $\bar{X}$	Iodine $\bar{X}$
Clearness of the treated water.	5.7	3.1
Speed of treating the water.	4.5	4.1

In addition, appearance and odor characteristics of the treated water were compared in the survey. On an appearance scale (0=clear - 9=cloudy), the Chlor-Floc-treated water received a mean rating of 2.8 while the iodine-treated water received a mean rating of 5.9. Results of a paired t-test showed that the Chlor-Floc-treated water was rated significantly clearer than the water treated with iodine tablets ($t=3.19$, $df=20$, $p<.01$). The odor of the water was also rated on 9-point scale (0=none - 9=strong). The Chlor-Floc and iodine systems received ratings of 5.7 and 4.2, respectively. No significant difference was found for the odor of the water.

Information collected during the focus group discussion may explain the ratings mentioned above. Soldiers expressed that they would prefer to use the Chlor-Floc system in the field in place of the iodine tablets because they feel using the Chlor-Floc system provides them with "much more palatable water." They would rather have the clear water that the Chlor-Floc system produces as opposed to the rather "murky" water produced by using the iodine tablets. The majority of the group felt that they were getting "cleaner" water when they used the Chlor-Floc system and that they would be prompted to drink more of this cleaner water. However, questionnaire data revealed that 74% of the respondents would like to have the option to be able to use both systems when in the field. Soldiers would use the Chlor-Floc system when they were going to be stationary for the amount of time needed to treat the water and they would use the iodine tablets when they had to "be on the move."

Given the information provided above, we feel that the Chlor-Floc water purification system should be evaluated again on a larger scale with a Special Forces unit.

APPENDIX B

CONSUMER TASTE TEST OF CHLOR-FLOC AND IODINE TREATED TAP WATER

SUMMARY

JUNE, 1991

APPENDIX B

Consumer Taste Tests

The main findings of the Biological Science Division at Natick's Soldier Science Directorate that relate to consumer tests of water treatment methods are as follows:

1. Except for acceptability of untreated tap water, serving temperature had virtually no effect on acceptability or perceived intensities of the other attributes studied.

2. Chlor-Floc-treated water was somewhat more acceptable than Iodine-treated water although it was disliked slightly.

3. Iodine-treated water had a higher perceived color level.

4. Both treated waters had equivalent odor levels.

5. Both treated waters had equivalent intensity levels when the question asked was <u>chlorine flavor</u>. However, when the question was the level of <u>medicinal flavor</u>, the iodine-treated water was rated higher in intensity than the Chlor-Floc-treated water.

6. The aftertaste question suggested that the iodine-treated water had a longer-lived carryover in the mouth than the Chlor-Floc-treated water.

7. Panel comments suggested no additional attributes not rated on the six rating scales.

The statistical data on these findings are summarized in Table B-1.

Table B-1

Taste Test Results
(N=118)

Overall Acceptability:

DISLIKE EXTREMELY 1	2	DISLIKE MODERATELY 3	4	NEITHER LIKE NOR DISLIKE 5	6	LIKE MODERATELY 7	8	LIKE EXTREMELY 9

CHLOR-FLOC Mean Rating	SD	Iodine Mean Rating	SD
3.9	1.9	2.3	1.6

Color:

Clear 1	2	3	4	5	6	7	8	Yellow/ Orange 9

CHLOR-FLOC Mean Rating	SD	Iodine Mean Rating	SD
0.75	1.2	6.8	2.0

Odor:

None 1	2	3	4	5	6	7	8	Strong 9

CHLOR-FLOC Mean Rating	SD	Iodine Mean Rating	SD
5.6	2.5	5.9	2.8

Chlorine-Like Flavor:

None 1	2	3	4	5	6	7	8	Strong 9

CHLOR-FLOC Mean Rating	SD	Iodine Mean Rating	SD
4.9	2.8	4.7	3.2

Medicinal-Like Flavor:

None 1	2	3	4	5	6	7	8	Strong 9

CHLOR-FLOC Mean Rating	SD	Iodine Mean Rating	SD
2.3	2.6	5.2	3.3

Aftertaste:

None 1	2	3	4	5	6	7	8	Strong 9

CHLOR-FLOC Mean Rating	SD	Iodine Mean Rating	SD
3.7	2.6	5.8	2.6

APPENDIX C

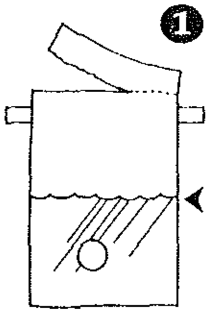
EMERGENCY DRINKING WATER PURIFICATION PROCEDURE

COMMERCIAL ITEM DESCRIPTION A-A-52122

KIT, WATER PURIFICATION, EMERGENCY (5)

1993

EMERGENCY DRINKING WATER PURIFICATION PROCEDURE

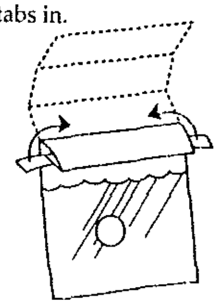


1 Tear off top of plastic water treatment bag at perforation

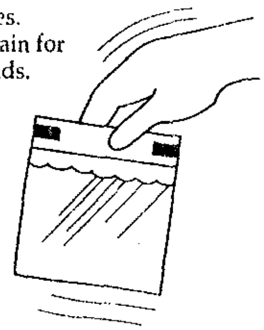
Fill halfway with water. Add 1 tablet.

CAUTION: Do not use canteen to fill plastic water treatment bag. Canteen may become contaminated. Fill bag directly from water source.

2 Fold bag tightly three times and fold tabs in.



3 Hold bag firmly and shake until tablet dissolves. Swirl 10 seconds. Let sit in canteen holder for 4 minutes. Swirl again for 10 seconds.



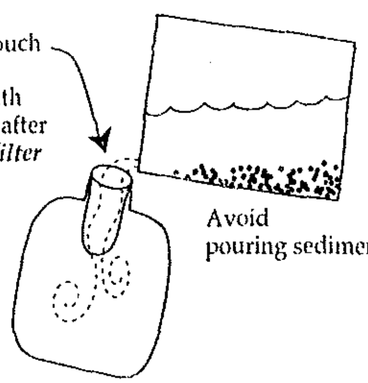
4 Let bag sit for 15 minutes.

CAUTION: Do not drink from the bag! It is still contaminated and must be filtered before drinking or it may cause stomach and intestinal disorders

5 Insert filter pouch

Rinse filter with treated water after use. *Always filter through same side of the cloth.*

Discard filter at the end of the day.



Avoid pouring sediment

6 Rinse sediment from treatment bag. Save bag for water treatment only.

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